RELATION BETWEEN RAINFALL AND RUN-OFF IN HILLEBRAND GLEN, NUUANU VALLEY, OAHU, HAWAII.

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[U. S. Geological Survey, Honolulu, Hawaii, Feb. 14, 1917.]

Little information is available concerning the relation between rainfall and run-off in the narrow, precipitous valleys in the Hawaiian Islands, and especially those in the vicinity of Honolulu, that are being utilized more and more as sources of municipal water supply.

The records collected in the islands by the United States Weather Bureau and the United States Geological Survey afford invaluable general information concerning rainfall, but have seldom been coordinated with records of run-off to establish factors adaptable to specific localities.

The practice of trying to solve Hawaiian Island problems by means of run-off factors derived from observations on the mainland at points differing greatly in climatic, geologic, and topographic features gives at best very unsatisfactory results. Local investigations of the relation between rainfall and run-off should be of great value in making storage estimates for future floods.

The information here presented was obtained by the water commission of the Territory of Hawaii in an intensive investigation of the rainfall and stream flow in Hillebrand Glen, Nuuanu Valley, Oahu, from May to December, 1916. At the expiration of the term of the commission, December 31, 1916, the work was continued by the Territorial Division of Hydrography, cooperating with the United States Geological Survey.

A unit of the municipal water supply of the city of Honolulu comprises four storage reservoirs—designated as reservoirs Nos. 1, 2, 3, and 4—in Nuuanu Valley, Oahu, approximately at elevations 400, 700, 800, and 1,000 feet, respectively, above sealevel (fig. 1). Reservoir No. 4 is the largest and the only one of the group that has never been filled to capacity.

Hillebrand Glen is a long, narrow, heavily forested V-shaped valley less than one-half square mile in area, lying between the western ridge of Nuuanu Valley and a southern spur from Mount Lanihuli that forms the western slope of Nuuanu Valley above reservoir No. 2 (figs. 2 and 3).

Maole Stream, in Hillebrand Glen, is formed from several small intermittent tributaries that cascade down the steep sides of the valley during periods of heavy rainfall (fig. 4). In ordinary dry weather the stream is exceedingly small, usually flowing from 25,000 to 30,000 gallons per day (0.04 to 0.05 second-foot).

The so-called "Hillebrand Glen project" of the city of Honolulu is a scheme to utilize the storm waters of Maole Stream for storage in reservoir No. 4 by constructing a diverting dam, tunnel, and lined open ditch. The increased storage will provide additional water for Nuuanu Valley and increase the power available at the municipal electric-light plant at reservoir No. 1.

So far as the furtherance of the Hillebrand Glen project was concerned, the problem of paramount importance to the commission was the determination of the amount and distribution of the seasonal stream flow of Maole Stream at the proposed point of diversion. Other considerations involved were the relation between rainfall and run-off in Hillebrand Glen and the relation between the rainfall in the glen and in Nuuanu Valley proper, where records of rainfall for 27 years had been collected by the United States Weather Bureau.

The water commission installed for its investigation a weir gaging station equipped with a Stevens continuous water-stage recorder and three raingages distributed in the glen at different elevations (fig. 1). Two of these, gages Nos. 1 and 2, were furnished by the United States Weather Bureau and were read daily. Raingage No. 3 was read weekly.

Table 1 [1] shows discharge in million gallons per day of Maole Stream, in Hillebrand Glen, from May 23, 1916, to January 31, 1917, obtained from the water-stage recorder. Tables 2 [1] and 3 [1] are weekly and monthly summaries, respectively, of the rainfall records obtained in Hillebrand

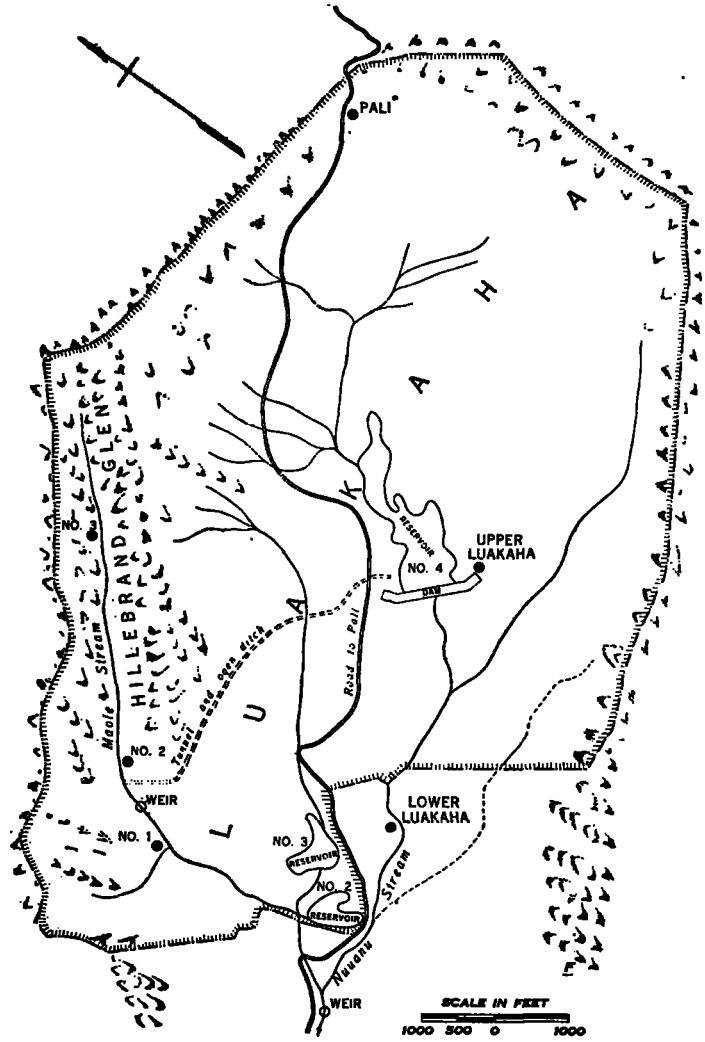

FIG. 1.—Map showing location of Hillebrand Glen in Nuuanu Valley, and location of rainfall (●) and stream gaging (○) stations.

Glen and in Nuuanu Valley proper from June to December 1916, by the water commission. Each record has been compared weekly and monthly with that for Lower Luakaha, for which a 27-year record is available. The ratios computed agree very closely and indicate that a monthly comparison of rainfall in Hillebrand Glen and Nuuanu Valley proper will give results about as satisfactory as a weekly comparison. This enables us to place more reliance on the long-time monthly comparison.

The mean rainfall and mean run-off for various well-defined storms have been compiled in Table 4, [1] which is

[1] Tables 1–5, inclusive, have been omitted, as their information seems sufficiently presented by the diagrams herewith.—EDITOR.

FIG. 2.—Hillebrand Glen from trail leading from Reservoir No. 2 in Nuuanu Valley. X shows location of Hillebrand Glen raingage No. 1.

FIG. 3.—General view downstream from below weir gaging station, showing Hillebrand Glen merging into Nuuanu Valley. Hillebrand Glen raingage No. 1 in foreground.

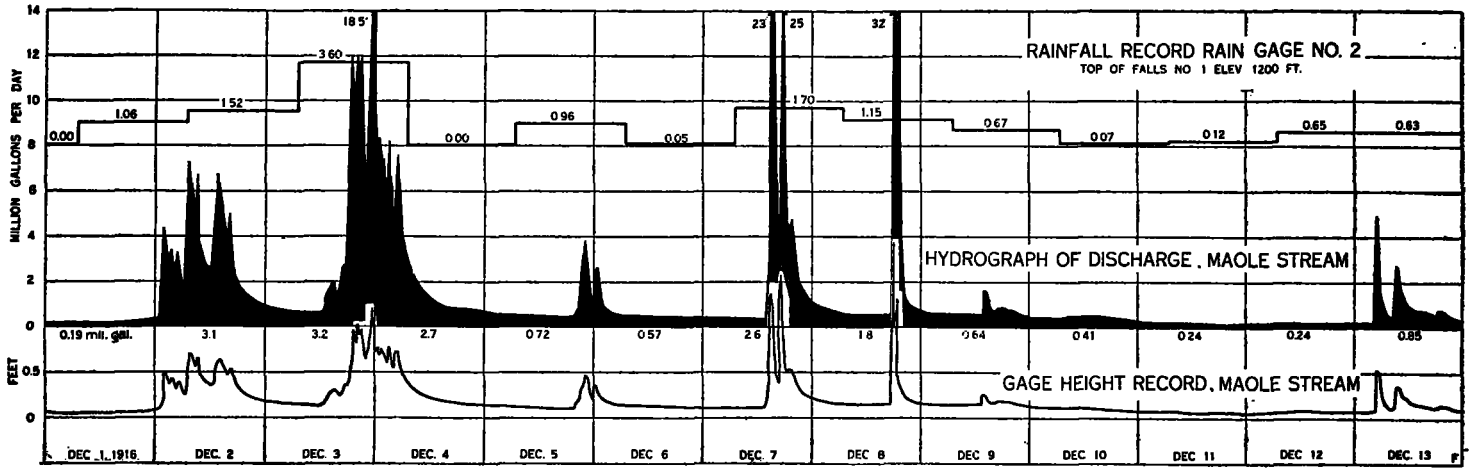

FIG. 4.—Hydrogram of typical flood periods, Maole Stream, Hillebrand Glen, December, 1916.

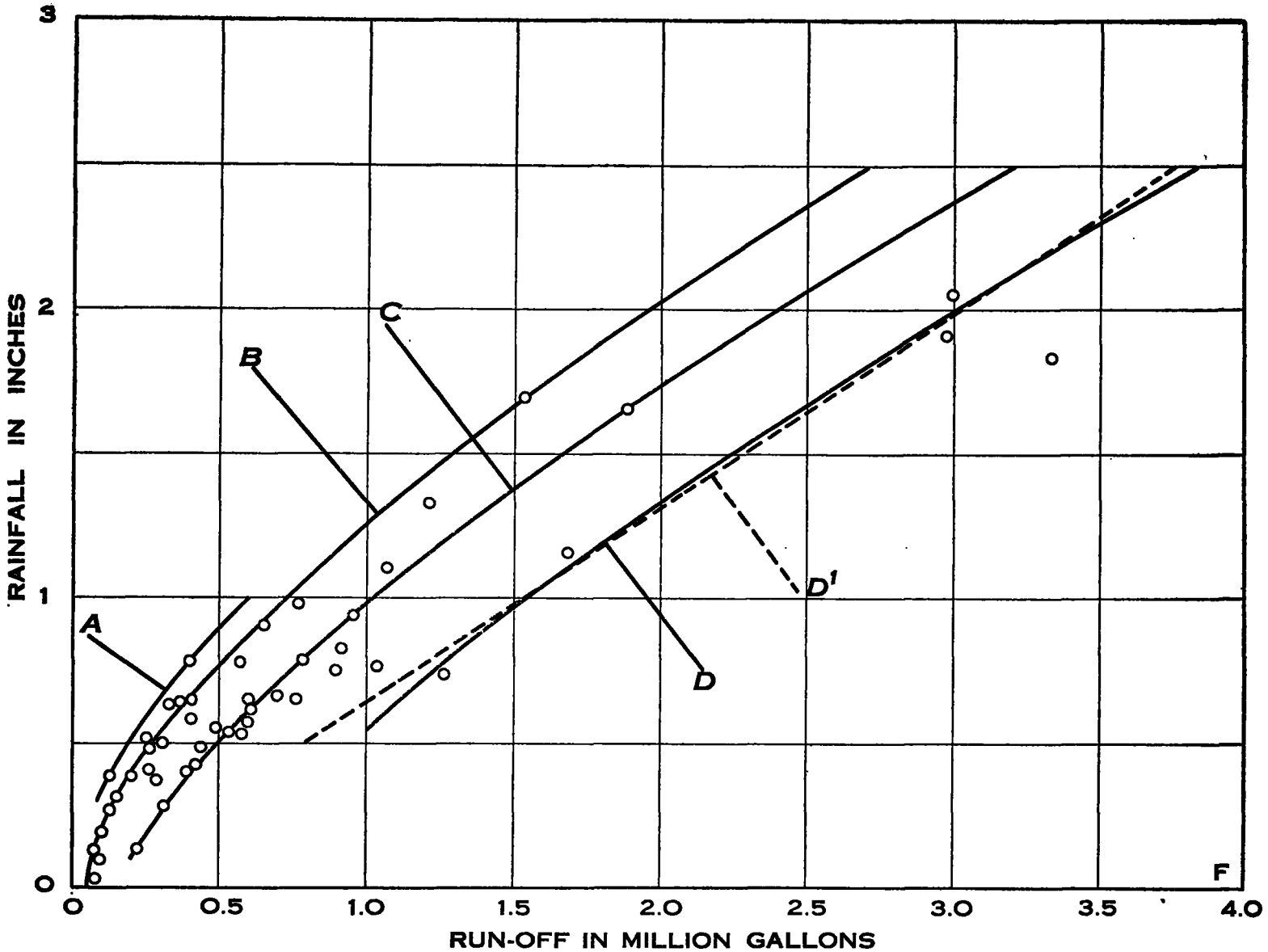

FIG. 5.—Curves of relation between rainfall and run-off, Hillebrand Glen, Nuuanu Valley. Rainfall from raingage No. 2; run-off from weir-gaging station (Stevens recorder); plotted points represent mean values for periods of several days.

A=Storms preceded by period of very dry weather;
B=Storms preceded by period of very light showers;
C=Storms preceded by period of moderate precipitation;
D, D'=Storms preceded by period of heavy precipitation.

based on a hydrograph comparison of the flow of Maole Stream and the rainfall in Hillebrand Glen recorded by raingage No. 2 (see fig. 4).

Figure 5, which has been prepared from Table 4, shows typical relation curves, *A*, *B*, *C*, and *D* (*D'*) between rainfall and run-off in Hillebrand Glen applicable for storms preceded by periods of dry weather or periods of light, moderate, or heavy precipitation. The curves are in general parallel, differing in position according to the previous

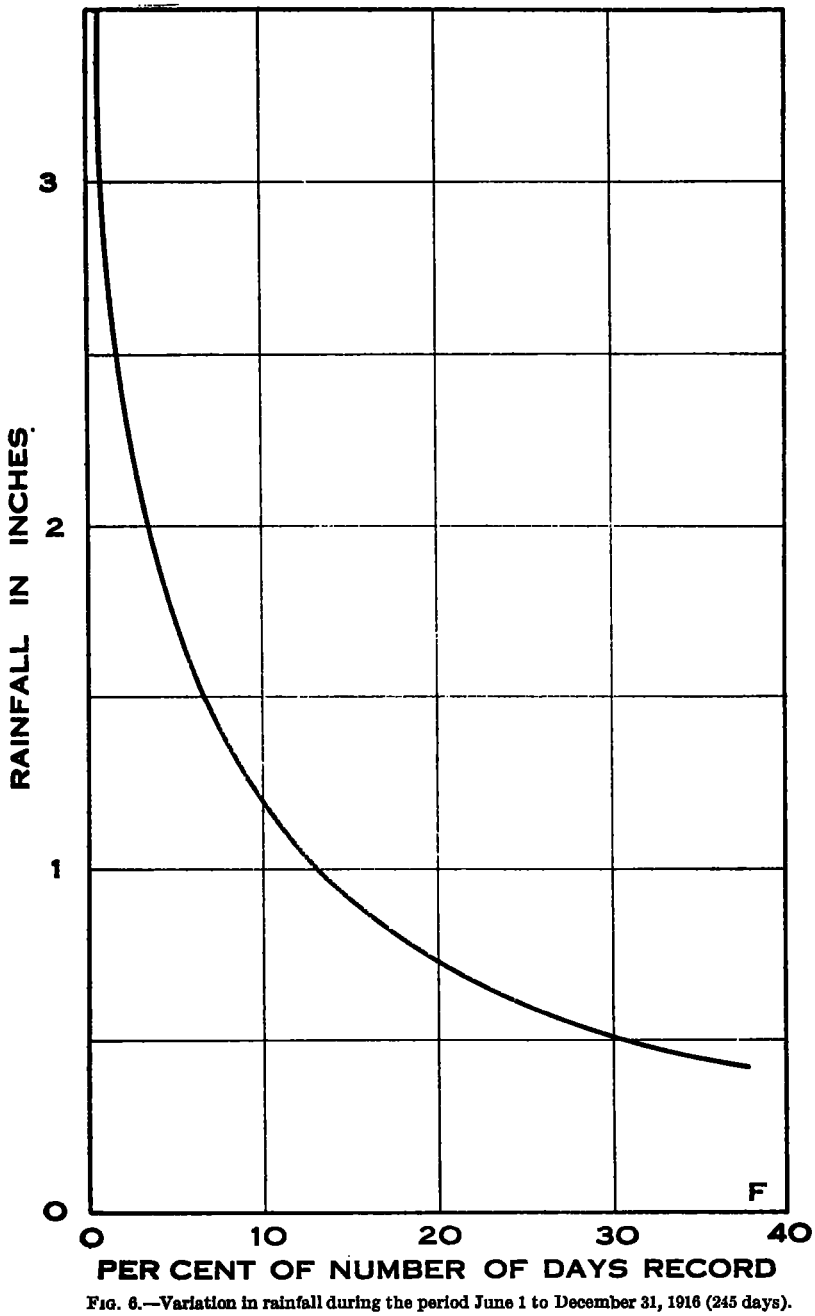

FIG. 6.—Variation in rainfall during the period June 1 to December 31, 1916 (245 days).

saturation of the soil. It will be understood that an infinite number of relation curves might be drawn to satisfy all possible degrees of soil priming.

Table 5 [1] shows the variation in rainfall from June 1 to December 31, 1916, and the number of days on which the rainfall was above stated amounts. Figure 6 shows these data in graphic form. It will be observed that the daily rainfall was 1.5 inches or more for less than 6 per cent of this period of 245 days. It averaged less than 0.5 inch for the entire period.

Table 6 (here Table 1) shows the per cent of run-off to rainfall computed from relation curves developed from records obtained from June 1 to December 31, 1916. Too few heavy storms occurred during this seven months period to define curve *D* as definitely as curves *B* and *C*. *D'* shows another possible relation for storms of class *D*.

TABLE 1.—*Relation between rainfall and run-off, Hillebrand Glen, Nuuanu Valley.*

[Drainage area at weir gaging station, 0.3 square mile.]

Precipitation.		Run-off.					Per cent of run-off to rainfall.				
Inches.	Gallons on drainage area.	A.	B.	C.	D.	D'.	A.	B.	C.	D.	D'.
		Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*					
½	2,600,000	190,000	270,000	500,000	950,000	780,000	7.3	10.4	19.2	36.5	30.0
1	5,210,000	600,000	720,000	1,020,000	1,550,000	1,550,000	11.5	13.8	19.6	29.8	29.8
2	10,420,000	.....	1,950,000	2,400,000	3,010,000	3,010,000	....	18.6	23.0	34.6	34.6

NOTE.—Run-off values were obtained from relation curves developed from rainfall and run-off during period June to December, 1916. (See fig. 5.)

From Table 1 it is seen that the run-off factors for Hillebrand Glen for the period June 1 to December 31, 1916, varied from practically nothing to about 35 per cent, according to the intensity of the storm and the previous degree of saturation of the soil. The mean average run-off is 20 per cent.

The period covered by this investigation has been very short and the work should be continued for a longer period in order to determine the run-off for periods of heavy precipitation.

The following estimate of the run-off from Hillebrand Glen is based on the rainfall and run-off records obtained to date and the long-time records of rainfall from Luakaha.

The rainfall monthly normals for Lower Luakaha cover a period of 27 years—from 1890 to 1916; those for Upper Luakaha cover a period of 12 years—from 1905 to 1916. They are as follows:

Normal monthly rainfall in Luakaha Valley.

	Upper Luakaha.	Lower Luakaha.
	Inches.	*Inches.*
January	11.72	9.98
February	10.06	11.88
March	12.37	13.60
April	13.90	13.02
May	15.50	11.76
June	11.36	9.95
July	11.12	10.51
August	13.60	12.21
September	14.53	11.95
October	10.49	10.81
November	14.99	13.41
December	17.18	14.59
Year	156.82	143.67
Average monthly	13.07	11.97

From the "average monthly" normals it is found that rainfall at Upper Luakaha is 109 per cent of that at Lower Luakaha, a relation which agrees closely with that obtained from weekly rainfall records for June to December, 1916 (see Table 2*). For that period the precipitation recorded at gage No. 2 in Hillebrand Glen, was 103 per cent of Lower Luakaha. The normal monthly rain-

[1] Tables 1-5, inclusive, have been omitted, as their information seems sufficiently presented by the diagrams herewith.—EDITOR.

fall for Hillebrand Glen would be $11.97 \times 1.03 = 12.33$ inches.

Actual run-off determination made by the water commission from June 1, 1916 to January 31, 1917, are as follows:

Monthly run-off in million gallons, June, 1916, to January, 1917.

1916.	
June	5.12
July	6.83
August	14.46
September	7.56
October	14.60
November	22.66
December	37.56
1917.	
January	19.92
Total, 245 days	128.68

The average daily run-off = 0.53 million gallons, or 530,000 gallons per day.

The total rainfall recorded by raingage No. 2, in Hillebrand Glen, June, 1916, to January, 1917, was 113.92 inches, or 0.46 inch per day. This quantity corresponds to a storage of $5{,}280 \times 5{,}280 \times 0.3 \times 7.48 \times \frac{0.46}{12} = 2{,}400{,}000$ gallons per day.

The per cent of actual run-off to actual rainfall for this 8-month period was $\frac{530{,}000}{2{,}400{,}000} = 22$ per cent.

This result agrees reasonably with the average ratio derived from a consideration of the rainfall–run-off relation curves (see fig. 5).

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Twenty-two per cent of 12.33 inches or 2.71 inches would be the average run-off per month, or 2.71 feet per year from Hillebrand Glen. This would amount to 170,000,000 gallons per year storage, or 465,000 gallons per day (0.46 million gallons per day).

MEAN LAKE LEVELS DURING APRIL, 1917.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., May 7, 1917.]

The following data are reported in the Notice to Mariners of the above date:

Data.	Lakes.			
	Superior.	Michigan and Huron.	Erie.*	Ontario.
Mean level during April, 1917:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sealevel at New York	602.28	580.78	572.57	246.24
Above or below—				
Mean stage of March, 1917	−0.05	+0.32	+1.04	+1.07
Mean stage of April, 1916	−0.06	+0.88	+0.12	−0.16
Average stage for April, last 10 years	+0.72	+0.63	+0.16	−0.14
Highest recorded April stage	−0.41	−2.45	−1.61	−2.19
Lowest recorded April stage	+1.74	+1.56	+1.31	+1.40
Average relation of the April level to—				
March level	±0.0	+0.2	+0.6	+0.5
May level	−0.3	−0.3	−0.4	−0.5

*April, 1916, level of Lake St. Clair was 575.21 feet.